Studies on the development of young Tufted Duck

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Introduction

When the Wildfowl Trust began a breeding biology study on ducks at Loch Leven, Kinross (Boyd and Campbell 1966), this became associated with the International Biological Programme's Project there. The aim of the I.B.P. was to draw up a complete energy-flow budget for the loch eco-system, which must include Tufted Duck *Aythya fuligula* feeding wholly within the loch. It was quite feasible to measure egg production, and its variation from season to season. It was much more difficult to estimate the survival of young, though this was clearly very low. It was impossible to follow their growth since this necessitated frequent recapture of the same individuals. Rearing Tufted Duck in captivity could provide growth data approximating to the wild situation, but the only previous study was that of Veselovsky (1951) based on but five unsexed birds, from a different stock (breeding in Czechoslovakia). A captive rearing programme was therefore undertaken.

It was undesirable to remove too many birds from the eco-system, so other studies were tied in with the primary one of measuring growth rate and food conversion. The internal reserves, in yolk and liver, around hatching had been studied extensively for the Mallard *Anas platyrhynchos*—the other main breeding duck at Loch Leven—by Kear (1965a). A set of comparable data was required for the Tufted Duck to indicate whether they were more likely to survive the critical period before feeding starts. The rate at which insulating fat deposits were laid down, and in which parts of the body, could have a bearing on the later survival of the birds. A comparative study of this aspect in Mallard and Tufted Duck, together with the rate of calcification of the bones, was made jointly with Dr. A. Evans and the results will be published elsewhere.

Material

Eleven clutches of near-hatching Tufted Duck eggs were collected from Loch Leven, under a licence issued by the Nature Conservancy, and hatched at Slimbridge. One clutch was taken locally and the ducklings reared with the Scottish birds. The 29 remaining at the end of the investigation, aged ten weeks, were released, with the feathers of one wing clipped, on to the main pond in the Wildfowl Trust enclosure. This was because a Ministry of Agriculture regulation did not permit their re-introduction into Scotland from England. A few bred the following spring, some probably with wild mates. All gained the power of flight that summer and joined the local wild population. Of the ducklings examined, 47 were males and 47 females, indicating an even sex ratio.

Methods

The ducklings were reared for the first 14 days in a large indoor cage. Two 250 watt lamps provided warmth, newspaper was used as flooring and terry-towelling as bedding. Initially, water was available only in small dishes and was changed frequently. At two weeks of age, the birds were moved into a shed with a wire mesh floor and a shallow, two-foot-square water tray. Overhead heating was again provided. At three weeks, they went outside on to grass with twice the quantity of water and with heat only provided in a shelter at night. At eight weeks they were moved again, to an unheated pen with a fairly large pond.

Food for the first month was chick starter crumbs (3% oil, 19.5% protein and 4% fibre) and subsequently pullet grower crumbs (3% oil, 16.5% protein and 5% fibre). A handful of duckweed *Lemna* and a small amount of quartz grit were added to the water daily. For the first seven days, some live food was offered to encourage the young birds to feed. Maggots and meal worms were the principal items, but flies, shrimps, moths and locust hoppers were given in small quantity.

Soon after hatching, the ducklings were sexed by cloacal examination and individually marked with numbered wing-tags. Weights, wing measurements and plumage changes were noted every two or three days.

Food reserves at hatching

The object of this part of the study was to assess the Tufted duckling's body, yolk and liver size at hatching. On these reserves depend in part its ability to survive until proper feeding is established.

Typically the brood spends a few hours in the nest and then follows its mother to the feeding grounds. If the weather is unfavourable, the parent may not leave until later. Extensive journeys are necessary if the nest is far from the feeding areas. As the Mallard's food reserves at hatching have been fully investigated (Kear 1965a; Markstrom 1966) indirect evidence on the survival potential of Tufted ducklings might be obtained by extrapolation.

Energy for embryonic development, for hatching, for locomotion between nest and food and for general metabolism until feeding starts, all comes from material laid down in the egg. Here, most of the calories are in the yolk. Although no tests have been made to compare the nutritive composition of eggs of waterfowl species, Lack (1968a) has established that the proportion of yolk does not vary significantly through the group. Factors that do differ quite widely are the absolute size of egg and yolk, and their size relative to that of the laying female (Lack 1968a, b).

The average fresh weight of 13 Tufted Duck eggs laid at the Wildfowl Trust was 53.3 gm. (47.5—59.0 gm.). These were produced by the released birds of Loch Leven or English stock at one year old and may have been slightly smaller than normal. Eggs laid in the wild are reported to weigh between 52.3 and 61.0 gm. (Isakov 1952), 55.7 gm. on average (49.1—60.5 gm.) for a sample of 23 (Niethammer 1938), 57 gm. (Heinroth 1922) and 56 gm. (Schönwetter 1960-61). The last figure was calculated from the linear measurements of 300 eggs and is probably the most reliable. K. F. Laughlin (pers. com.) has weighed 96 fresh eggs from Loch Leven and reports an average weight of 55.1 gm.

The average weight of females just before laying is not as easily obtained. Veselovsky (1951), combining figures from a number of sources, reported the range for adult females as 656 to 948 gm. Periods of high body weight seem to occur before laying in spring and before migration in autumn. More than 150 females have been caught on the nest at Loch Leven, but as they had already laid at least a part of their clutch, the figures cannot be used for the present purposes. Isakov (1952) gave 795 to 955 gm. as the range of May weights in the U.S.S.R., with 840 gm. as an average. By extrapolation, K. F. Laughlin (pers. com.) calculates a similar figure for Loch Leven birds just prior to nesting. If this is taken as a typical breeding female weight, each egg constitutes 6.7% of the female's body. This compares with a relative egg weight of 5.3% in the Mallard (Kear 1965b).

The weight of the egg is related directly to that of the young that hatches from it, and the size of the duckling is probably of particular importance in determining survival when conditions are rigorous. Some figures are available on the weight of Tufted ducklings soon after hatching: 37.4 gm. (35—41 gm.) n = 13 (Veselovsky 1951), 35.0 gm. (31.5—38.2 gm.) n = 4 (Smart 1955), 34.1 gm. n = 11 (Koskimies and Lahti 1962), and 35.6 gm. n = 38 (K. F. Laughlin pers. com.). During the present study, 100 were weighed to the nearest 0.5 gm. and these scaled on average 35.3 gm. (30.0—43.0 gm.). No previous investigation has had so many individuals available, and since there is no great variation between the published figures, 35.3 gm. will be taken as typical.

Table I gives average day-old weights of ducklings of nine other *Aythya* species, plus that of the Mallard. Average adult female weights are also shown. These are not of the same order of accuracy as the duckling weights since sample sizes are sometimes not known and adult weight varies through the year. Nevertheless, a ratio has been calculated between the size of the duckling and its parent, and this is given in the last column. The size of the downy Tufted relative to that of the mother is seen to be high. In continental diving ducks, the ratio of duckling to female weight seems to correlate fairly closely with latitudinal distribution (Delacour 1959) and probably, therefore, with the rigorousness of the climate. Thus, Tufted Duck, Lesser Scaup *A. affinis*, Canvasback *A. valisneria*, Scaup *A. marila*, and Pochard *A. ferina*, with relatively large youngsters, breed as far as the arctic circle or beyond to 70°N. Common White-eye *A. nyroca*, Redhead *A. americana* and Baer's Pochard *A. baeri*, with rather smaller ducklings, do not lay above 58°N., while Australian White-eye *A. australis*, with relatively the lightest offspring, nests in the warm near-tropics, not beyond 42°S. The New Zealand Scaup *A. novae-seelandiae* is a complete exception. It has presumably evolved its small clutch of large eggs and a heavy duckling in relation to features other than climate prevailing on remote islands (Lack 1970).

The procedure followed in assessing yolk and liver size in Tufted ducklings was described in Kear (1965a). Five individuals from different clutches were examined at approximately 48 hours before hatching and at exactly four, 24

Table I. Weights of captive *Aythya* and Mallard ducklings at hatching (4-24 hours old).

Species	*Number in sample*	*Mean weight in gm.**	*Mean female weight in gm.*	*Source of female weight*	*Duckling as % of female*
novae-seelandiae	82	43.9(35.5—51.5)	700	Lack (1968)	6.3
fuligula	100	35.3(30.0—43.0)	840	Isakov (1952)	4.2
affinis	34	32.1(27.5—39.0)	794	Kortright (1943)	4.0
valisneria	10	44.7(43.0—48.0)	1115	Dzubin (1959)	4.0
marila	16	39.1(26.0—47.0)	1000	Isakov (1952)	3.9
ferina	37	37.2(29.5—46.5)	947	Isakov (1952)	3.9
nyroca	82	22.0(16.5—28.0)	600	Lack (1968)	3.7
baeri	33	23.9(18.5—27.5)	640	Lack (1968)	3.7
americana	65	35.5(27.0—42.0)	993	Weller (1957)	3.6
australis	92	29.3(21.0—40.0)	852	Frith (1967)	3.4
Anas platyrhynchos	100	34.1(26.5—40.0)	1000	Lack (1968)	3.4

* *valisneria* from Dzubin (1959); all others original.

and 48 hours after hatching. They, and other sacrifices, were painlessly killed by euthanol injection. These samples were much smaller than those used in the Mallard study but large enough to indicate any major differences. Results are given in Table II.

In general, the Mallard and Tufted Duck show considerable similarity. The fresh egg of the Mallard weighs on average about 2 gm. less (Schönwetter 1960-61); as the proportion of yolk in both is initially 38% (Härms 1929-30; Lack 1968) the Tufted Duck in absolute terms has slightly more. Two days before hatching Tufted Duck still have more. At four hours after hatching, the amount and proportion of yolk in the ducklings is almost identical, and over two days of life in optimum conditions, it declines in a very similar manner.

The liver of the Tufted duckling is also initially larger than that of the Mallard, although by 24 hours of age it was identical in weight in the two species. The resources of the yolk sac are drawn on mainly during and just after hatching, when the expenditure of energy must be enormous. At the same time, much of the food material in the yolk is transferred via the blood to other stores such as the subcutaneous body fat and the liver. Thus, liver weight increases although the ducklings do not feed.

The Tufted Duck seems to be at an advantage, at least during the first 24 hours. It is slightly larger and has proportionately more yolk and liver than the Mallard. Some differences at a very early age are known between the Mallard and the Tufted Duck. For instance, Fabricius (1964) stated that young Tufted Ducks rarely leave the nest earlier than 24 hours after hatching, which is about 12 hours later than the Mallard (Kear 1965a; Bjärvall 1968). Further, Tufted Duck frequently nest far from suitable feeding areas; Hildén (1964), for instance, reported

Table II. Mean body, yolk sac and liver weights of ducklings (in grams).

Time from hatching	*No.*	*Total body*	*Yolk*	*Liver*	*Yolk %*	*Liver %*
		Tufted Duck				
−48 hrs.	5	46.1	11.5	1.0	25.0	2.2
+ 4 hrs.	5	37.5	3.4	1.5	9.1	4.0
+24 hrs.	5	32.5	1.8	1.6	5.5	4.9
+48 hrs.	5	32.4	0.5	1.7	1.5	5.2
		Mallard (from Kear 1965a)				
−48 hrs.	50	44.9	9.1	0.7	20.3	1.6
+ 4 hrs.	47	35.3	3.2	1.0	9.1	2.8
+24 hrs.	57	32.1	1.7	1.6	5.3	5.0
+48 hrs.	52	35.7	0.5	1.9	1.5	5.3

regular journeys of 4 km. across open sea by newly hatched broods. At Loch Leven itself, the main nesting island of St. Serf's affords poor conditions for duckling survival and broods are led to the loch shore 1 km. away.

In captivity Tufted ducklings do not start to feed as soon as Mallard (some, according to Veselovsky (1951), not until their third day) and begin gaining weight some 24 hours later (see Table II). This is possibly an artifact of the conditions but may imply a real difference in early feeding techniques which requires that the Tufted duckling be more mature. It is certainly less catholic in its tastes and appears to be much more dependent on live (moving) food than *Anas*, a point stressed by Veselovsky (1951), Gillham (1958) and Hildén (1964). Fabricius (1945) indeed postulated that insect food was indispensable for maintaining the waterproofing of their down. Tufted ducklings lead a particularly vigorous life, catching insects with rapid leaps and dashes (Hildén 1964) and making their first dives to the bottom at about 48 hours old (Fabricius 1951), at a time when the Mallard is still only dipping its head under the water (McKinney 1965). Koskimies and Lahti (1964) demonstrated that Tufted ducklings expend more energy and are more cold-tolerant. They exposed unfed Tufted ducklings, one day old or less, to air temperatures of 8° to 10°C. and yet the birds maintained their normal body temperature for as long as 18 hours. Their relative heat production was calculated to be 10% higher than that of young Mallard.

All these factors (together with that of rapid embryonic development in the egg probably reflected in a shorter incubation period) indicate a high metabolic rate. This is associated with good reserves of internal energy and presumably is necessary in order to cope with harsh environmental demands. The species has become adapted to a situation where feeding need not be established within the first day, but it seems likely that the duckling's condition could then deteriorate faster than does the Mallard's. Unless sound external nutrition were developed between 24 and 72 hours, high metabolism means that birds could not survive for a week without food, as recorded for Mallard (Marcstrom 1966). So weather and food availability at a rather precise period after hatching may be correspondingly more important to this species. In view of the compressed breeding season of the Tufted Duck (Boyd and Campbell 1966), the 'success' of any particular year may be based on conditions during a very few days.

Weight changes during development

Table III shows the actual weights of males and females up to ten weeks of age and the relative increases from the hatching weight (Table I). These relative weights are also plotted in Figure 1. Every two weeks five birds were sacrificed for the work on fat deposition and bone calcification. From four weeks onwards, only males were killed, in order to reduce variability in the small sample used. This study is being reported on separately by Dr. A. Evans.

Initially growth was rapid. By five weeks the birds had increased their weight 13-fold, and after another five weeks the males were over 18 times their birth-weight and the females over 16 times. At six weeks of age, the sexes were quite noticeably diverging in size and by the end of the experiment the females weighed only 90% of the males. This

Table III. Average weight in gm. of Tufted Duck reared in captivity.

	Males			*Females*	
Age in weeks	*No. in sample*	*Actual*	*Relative*	*No. in sample*	*Actual*	*Relative*
1	22	66.1	1.9	22	74.6	2.1
2	22	151.7	4.3	22	153.3	4.3
3	21	264.2	7.5	18	250.1	7.1
4	21	362.9	10.3	18	352.0	10.0
5	16	458.9	13.0	18	448.4	12.7
6	16	518.6	14.7	18	490.9	13.9
7	11	560.4	15.9	18	512.5	14.5
8	11	540.2	15.3	18	500.7	14.2
9	6	593.3	16.8	18	530.5	15.0
10	6	652.5	18.5	18	587.7	16.6

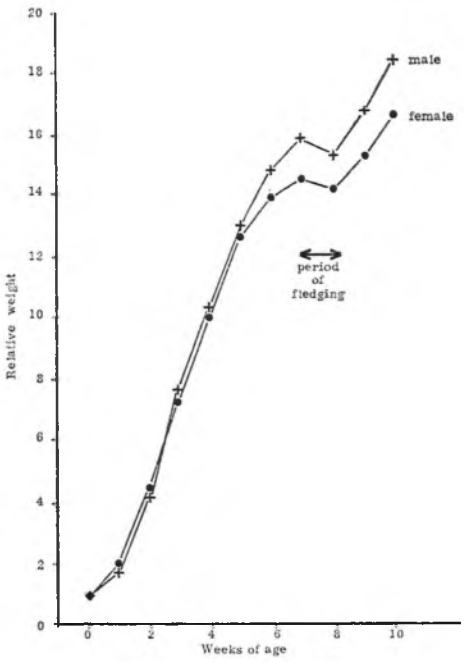

Figure 1. Relative growth indices of male and female Tufted Duck.

difference is probably about normal, at least until the females come into breeding condition (see figures in Bauer and Glutz 1969).

At fledging, already a period of probable physiological stress, the birds were moved to a more spacious pen with a large pond. Twenty-three of the 28 birds had already shown slight decreases in weight just prior to this move but after it every individual lost. Similar 'troughs' in the growth curve around fledging have been reported in Teal *Anas crecca*, Mallard, Gadwall *A. strepera*, Shoveler *A. clypeata*, Pochard, Common White-eye and Tufted Duck by Veselovsky (1953), in Redhead by Weller (1957), in Cape Shoveler *Anas smithi* and Cape Teal *A. capensis* by Brand (1961) and in Mute Swan *Cygnus olor* by Portman (1950). So they are commonplace in captivity and may occur in the wild in less than optimum conditions.

At ten weeks, the weight curves of the Tufted Duck had regained the line extrapolated from the two weeks before fledging, the recovery being particularly rapid between the 9th and 10th week. It was now early September and no further measurements were taken, but probably slow increase in weight continued. Eighty-one juvenile females caught at Loch Leven in the first two weeks of September averaged 619 gm. and 60 males averaged 666 gm. (C. Campbell pers. com.), slightly more than the ten-week-old juveniles in captivity. The weight of young wild birds during the second two weeks of September is little different: an average of 626 gm. for 23 females and 661 gm. for 28 males.

The rate of growth of the Scottish Tufted Ducks seems similar to that reported for five unsexed birds weighed to 55 days of age by Veselovsky (1951). Data on a number of other temperate or northern diving ducks have been published by Southwick (1953), Weller (1957), Veselovsky (1953, 1966), Dzubin (1959) and Elder (1954). Some weights in captivity at three weeks of age relative to those at hatching are shown in Table IV. The ratios are markedly similar to one another (varying only between 7.0 and 7.7) and consistently less than the initial weight gain found in five temperate dabbling species, also shown in Table IV. These, although often starting with relatively smaller ducklings, grow in three weeks to between 8.4 and 10.8 times their hatching weights.

After three weeks, species diverge more widely and individuals of the same species may grow at different rates depending, presumably, on such things as climate and food supply (or ability to make use of what is available). At seven weeks the Tufted Duck is on average 15

Table IV. Relative growth rates of 10 species of diving and dabbling ducklings raised in captivity, at three weeks of age. (Data from Southwick (1953), except *Netta rufina* (Veselovsky 1966) and *Aythya fuligula* (present study)).

Divers (Aythyini)		*Dabblers (Anatini)*	
Species	*Relative wgt. at 3 weeks*	*Species*	*Relative wgt. at 3 weeks*
A. americana	7.0	*Anas discors*	8.4
Netta rufina	7.1	*A. acuta*	8.9
Aythya valisneria	7.3	*A. platyrhynchos*	9.9
A. fuligula	7.4	*A. clypeata*	10.5
A. collaris	7.7	*A. americana*	10.8

times its hatching weight, Canvasback 20 times (Dzubin 1959), Red-crested Pochard *Netta rufina* 21 times (Veselovsky 1966), and Pintail *Anas acuta* 24 times (Southwick 1953). Many of the dabblers maintain their early lead in development and fledge more quickly than the diving species.

Plumage changes

Table V shows the progress of feathering; the age given is that when any bird first showed a particular feature. One female tended to be slightly more precocious than any of the males, especially in the early stages, but this may have been the result of individual rather than sexual variation.

Table V. Feathering sequence in Tufted Duck.

	First seen at Age (days)	
	♂♂	♀♀
Tail feathers starting to grow	14	13
Scapulars visible	18	15
First secondary through	22	20
First primary through	24	21
Feathers on cheek visible	25	24
Belly feathers visible	28	26
Belly completely feathered	31	30
White stripe across primaries and secondaries apparent		39
All down lost from head		40
First flights		49
Tuft obvious on head		56
All down lost from underwings and back		58

The first obvious feathers appeared on the shoulders and their growth spread downwards, around the wing. On the belly, feathering expanded rapidly from a narrow central line. Cheek feathering was first visible near the root of the bill and moved backwards over the crown and face. The last remnants of down were visible on the back of the head behind the eye, on the whole of the nape and on the dorsal part of the neck. Traces can be found on the 'small' of the back and under the wings even after fledging. The Tufted Ducks from Scotland tended to show the very early stages of plumage development before they had been observed by Veselovsky (1951). For instance, his birds grew their first contour feathers (scapulars) only at 20 days. The later stages of feathering seemed similar.

Differences between the sexes in eye colour, the males' being brighter yellow, were obvious by the 35th day. Voice was also becoming distinguishable at 37 days. By the 44th day, all females were making a recognisably adult sound (rendered by Veselovsky as 'karr'), while the males were still 'squeaking'. Further sexual differences in the juveniles are mentioned by Veselovsky (1951): the male can be distinguished from the female by a darker brown head and neck, and by his bluish-grey, as opposed to dark brown, bill. Both sexes have a short head tuft at eight weeks of age.

The very full descriptions of adult and immature plumages given in Witherby (1939) agree with observations made during the present study. The complete juvenile plumage lasts only until the birds are 14 to 16 weeks old. From then on, new feathers emerge and by the end of December, adult plumage is attained, although Tufted Ducks with notched tail feathers have been taken as late as April (R. King pers. com.).

Table VI and Figure 2 show changes in wing length from five weeks of age. The first quill to appear in the developing wing was a secondary at about three weeks, with the first primary a day or so later. From then on, growth proceeded

Table VI. Changes in average wing length in mm. of young Tufted Duck (sample sizes as in Table III).

Age in weeks	♂♂	♀♀
5	100.7	97.3
6	134.4	133.5
7	163.6	161.8
8	185.2	180.2
9	199.3	193.5
10	204.7	194.9
Range at 10 weeks	(198-209)	(189-202)

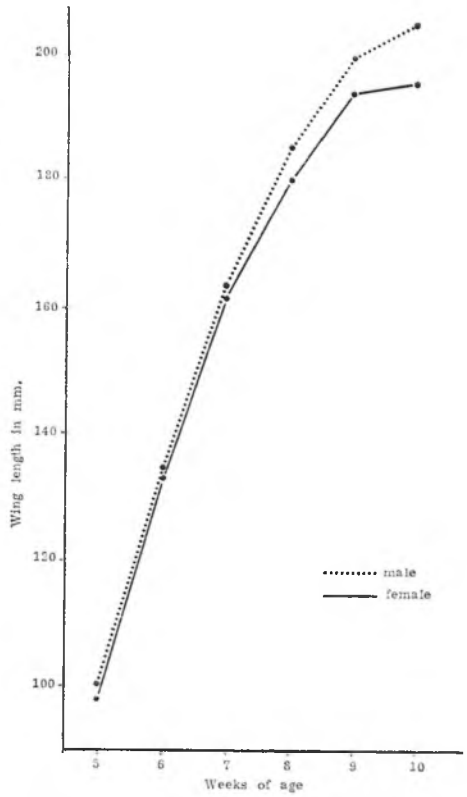

Figure 2. Wing lengths of young male and female Tufted Duck.

fairly uniformly in all quills. Wing measurement was of the standard chord, from carpometacarpus to the tip of the longest primary, the wing being closed and the flight feathers straightened but not flattened. Flattening by pressure at the carpal joint added on average 3.7 mm. (1.8%) to the length of the fully grown wing. At maximum wing length, errors of measurement did not exceed 2 mm. (1%).

The birds were capable of short flights before the wings were fully grown. The first bird (a male) seen lifting off the ground (at seven weeks) had wings measuring 177 mm., some 12% less than the average length for birds in their first winter. This was considered to have been reached at ten weeks of age. Schiøler (1926) gave an average of 197.9 mm. (190—214 mm) for 25 first year Danish males and 190.5 mm. (181—196 mm.) for 20 first year females. This is rather less than the Scottish birds reared in England but agrees well with figures obtained from wild birds at Loch Leven and Abberton, Essex. At Loch Leven 58 male juveniles caught in September had wings which averaged 198.7 mm., (162—215 mm.) and 83 females 191.9 mm. (174—204 mm.) (C. Campbell pers. com.). At Abberton 28 young males caught between September and February averaged 196.3 mm. (187—205 mm.) and 32 young females 192.8 mm. (180—200 mm.) (R. King pers. com.).

Date of fledging varies markedly between duck species with arctic and temperate forms tending to reach the flying stage earlier than tropical ones. Heinroth (1928) and Streseman (1931) also pointed out that in general dabbling ducks fledge faster than sympatric diving species. Undoubtedly, many *Anas* species do grow quickly: *crecca* flies in 5 weeks. Blue-winged Teal *discors* in 5½, Wigeon *penelope* in 6, *acuta* in 6½, *strepera* in 7 and *platyrhynchos* in 8, while Ring-necked Duck *Aythya collaris* and *ferina* are recorded fledging at 7½ weeks of age, *americana* and *valisneria* at 9 and *affinis* at 9½ (see Lack (1968) for all references). Streseman (1931) and Heinroth (1928) suggested a reason for the difference in the less aquatic life of dabblers, presumably leading to greater vulnerability to predators and pressure to shorten the period of relative helplessness. Put another way, divers can successfully exploit a 'difficult' food supply because the disadvantage of a slow growth rate is offset by a reduction in predation.

Changes in linear dimensions

In addition to wing length, a number of linear measurements were taken (with Vernier calipers, see B.T.O. (1965)) of the ducks sacrificed for the study of fat

Table VII. Average linear growth in mm. of young Tufted Duck (samples of 5).

	**1 day*	**2 weeks*	*4 weeks*	*6 weeks*	*8 weeks*	*10 weeks*
Culmen	14.1	26.3	33.7	37.2	39.2	40.2(38.9—41.8)
Head length	37.0	61.9	73.8	83.6	86.3	88.7(86.6—90.8)
Tarsus length	19.9	29.8	34.9	35.2	35.5	35.7(35.6—35.9)
Tarsus thickness	1.2	2.9	3.6	4.0	3.9	4.0(3.9— 4.1)

* mixed sex, other age groups males only

deposition and bone hardening (Evans in prep.). The averages are listed in Table VII.

The changes in body proportions were not uniform. The tarsus had reached near maximum length and thickness by the time the birds started to fly at seven weeks, while the head and bill continued to grow. Veselovsky (1951) gives the range of measurements of 15 three-month-old birds as bill 38—42 mm. and tarsus 35—40 mm., so the ten-week-old birds were probably full size. In Phillips (1926), the adult male range for the bill is said to be 38—40.5 mm., and for the tarsus 32—37 mm., and Schiøler (1926) cites an average of 39.5 (36—42 mm.) for the bill of 26 adult males in Denmark, and 36.8 (33—39 mm.) for the tarsus.

It is usual, in waterfowl, for the leg to develop quickly. The phenomenon is presumably an adaptation for life on water. Weller (1957) and Dzubin (1959) found that in two other diving *Aythya* species, tarsus length reached full size between six and eight weeks, although the bill continued to grow after the flying stages was reached. A similar finding was reported by Brand (1961) for *Anas smithi* and *A. capensis*, and Matthews and Campbell (1969) showed that in the Greylag Goose *Anser anser* the bill continued to lengthen slightly during the goslings' first winter.

Comparison of growth rates in different populations

It is possible that a population adapted to breeding at higher latitudes with a longer day length might mature faster. Results from the rather small samples (three females and seven males in the English group) did not bear this out. There was almost complete overlap in weight and wing length, at any age, with those from Scotland. Small average differences between populations breeding 5° apart might emerge from an investigation of more individuals.

Food consumption

A guide to the minimum food requirements of developing Tufted Duck in the wild can be obtained by assessing their food conversion rate in captivity. This gives the weight of food required per unit live weight gain.

An assessment based on the original study is somewhat inaccurate. No attempt was made to measure intake of *Lemna*, nor of the small invertebrates consumed, other than maggots and meal-worms. Some 'natural' food was also probably found in the outdoor pens. However, it was felt that none of these 'extras' were of great importance and they offset, to some extent, wastage due to spillage and loss to a few wild birds which managed to enter the pen.

An approximate total of 105 kg. of food was consumed by the group for a live weight gain of 26 kg., giving a factor of 4:1 to ten weeks of age. This is in close agreement with a factor for domestic ducklings (*Anas platyrhynchos* type) of 3.93:1 to eight weeks of age (M.A.F.F. 1960).

However, the calculations on food conversion made the assumption that the rate was constant. Brand (1961) showed that food consumption in *Anas capensis* and *A. smithi* declined from an average of 79 gm. per day, during a period of fast growth at four and five weeks, to 66 gm. per day (16% less) at 10 and 11 weeks when their growth curve was flattening out. Further, Holm and Scott (1954) demonstrated that on a 19% protein diet young *Anas platyrhynchos* consumed 1.76 lb. of feed per lb. gain in weight at three weeks, but 2.86 lb. per lb. at seven weeks. An exact analysis of individual intake of Tufted Ducks at various ages could not be made during the original study because all birds having reached three weeks of age were reared together. Also the total population gradually decreased as older males were eliminated. During the spring of 1970 it was possible to obtain a further clutch of eleven Tufted Duck eggs from Loch Leven. On the birds' 7th, 14th, 28th, 42nd, 56th and 70th day of age, food was restricted to a weighed amount to which only they had access. A polythene sheet enabled any spillage to be weighed with the uneaten portion at the end of the experiment. The birds were weighed at the beginning and end of 24 hours. Up to and including the 28th day, the ducklings had chick starter crumbs; subsequently pullet grower crumbs were given.

Table VIII confirms findings by other workers, that the weight gain/intake ratio is not constant during the growth period. As it is highest when the bird's intake is low, the overall rate is not the arithmetic average of the weekly values. To obtain really reliable figures it would be necessary to confine the birds in metabolism cages where total intake could be weighed daily. Such confinement might well introduce other complicating factors but should be the subject of further research.

Table VIII. Food consumption and food conversion of young Tufted Duck (average of 11 individuals, 3 males and 8 females).

Age in weeks	*Average food intake in 24 hrs. in gms.*	*Ratio of weight gain to intake*
1	23.0	1:1.99
2	34.1	1:1.8
4	57.8	1:2.3
6	87.0	1:9.6
8	48.0	1:8.8
10	74.4	1:9.0

These tests have relevance in that they allow calculation of the minimum impact of Tufted Ducklings on the ecosystem at each stage of their development. The minimum protein requirement can also be assessed. Holm and Scott (1954) found that for *Anas platyrhynchos*, *A. acuta* and *Aythya americana*, protein requirement for optimum early growth was 19%. The amount of protein in the diet fed to the Tufted Ducklings declined over the growth period, but was 18% on average. Thus, in captivity, a male Tufted duckling reaching 650 gm. weight at ten weeks consumes a minimum of 2,600 gm. of food, of which 470 gm. is protein.

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Summary

The growth period of the Tufted Duck *Aythya fuligula* is considered in a number of aspects. The size of the newly-hatched young relative to that of the mother is shown to be high in comparison with other diving duck and the Mallard *Anas platyrhynchos*. This may be related to a northerly breeding distribution. The internal food stores of yolk sac and liver were found to be marginally greater than those of the Mallard and perhaps give an advantage in very early life; however, the higher metabolic rate assumed for the Tufted probably causes more rapid depletion.

At five weeks of age birds were 13 times, and at ten weeks males were 18 times and females 16 times their hatching weight. This is slow in comparison with temperate dabbling ducks. Plumage characteristics and secondary sexual differences are described. The birds took their first short flights at seven weeks. The tarsus reached full size between six and eight weeks while the bill and head continued to grow after the bird could fly. No differences in weight or linear measures were found in birds originating from Scotland and England.

The food conversion rate over the first ten weeks was calculated to be approximately four units of food for every unit of liveweight gain. A total intake of 2,600 gm., including 470 gm. of protein, is therefore estimated to be required by a captive male Tufted Duck in that period.

References

BAUER, K. M. and U. N. GLUTZ V. BLOTZHEIM. 1969. *Handbuch der Vögel Mitteleuropas.* Frankfurt: Akademische Verlagsgesellschaft.

BJÄRVALL, A. 1968. The hatching and nest-exodus behaviour of Mallard. *Wildfowl* 19 : 70-80.

BRAND, D. J. 1961. A comparative study of the Cape Teal (*Anas capensis*) and the Cape Shoveler (*Spatula capensis*), with special reference to breeding biology, development and food requirements. Unpublished Ph.D. thesis, University of S. Africa.

B.T.O. 1965. *The Ringer's Manual.* British Trust for Ornithology publication.

BOYD, H. J. and C. R. G. CAMPBELL. 1966. A survey of ducks breeding at Loch Leven in 1966. *Wildfowl Trust Ann. Rep.* 18 : 36-42.

DELACOUR, J. 1959. *The Waterfowl of the World,* Vol. 3. London: Country Life.

DZUBIN, A. 1959. Growth and plumage development of wild-trapped juvenile Canvasback (*Aythya valisneria*). *J. Wild. Mgmt.* 23 : 279-90.

ELDER, W. H. 1954. The oil glands of birds. *Wilson Bull.* 66 : 6-31.

FABRICIUS, E. 1945. Om dietens inverkan på gumpkörtelns funktion hos andfågelsdunungar. *Orn. Fenn.* 22 : 33-45.

FABRICIUS, E. 1951. Zur ethologie junger Anatiden. *Acta Zool. Fenn.* 68 : 1-178.

FABRICIUS, E. 1964. Crucial periods in the development of the following response in young nidifugous birds. *Z. Tierpsychol.* 21 : 326-37.

FRITH, H. J. 1967. *Waterfowl in Australia.* Sydney: Angus and Robertson.

GILLHAM, E. H. 1958. Some notes on Tufted Ducks and their young in St. James's Park, London. *Bird Notes* 28 : 345-7.

HÄRMS, M. 1929-30. Oologische Untersuchingen über die Eier einiger Wasservögel. *Beitr. Fortpfl-bio. Vogel* 5: 19-21, 68-72, 97-103, 142-7, 161-9, 217-24; 6: 18-21, 49-51, 83-86.
HEINROTH, O. 1922. Die Beziehungen zwischen Vogelwicht, Eigewicht, Gelegegewicht und Brutdauer. *J. Orn.* 70 : 172-285.
HEINROTH, O. and M. 1928. *Die Vögel Mitteleuropas.* Vol. 3. Berlin.
HILDÉN, O. 1964. Ecology of duck populations in the island group of Valassaaret, Gulf of Bothnia, *Ann. zool. fenn.* 1 : 153-279.
HOLM, E. R. and M. L. SCOTT. 1954. Studies on the nutrition of wild waterfowl. *N.Y. Fish & Game J.* 1 : 171-87.
ISAKOV, Y. 1952. In *The Birds of the Soviet Union.* Ed. G. P. Dementiev. Moscow.
KEAR, J. 1965a. The internal food reserves of hatching Mallard ducklings. *J. Wildl. Mgmt.* 29 : 523-8.
KEAR, J. 1965b. A brief review of factors influencing egg size in a single species. *Ool. Rec.* 39 : 1-7.
KORTRIGHT, F. H. 1943. *The Ducks, Geese and Swans of North America.* Washington: American Wildlife Institute.
KOSKIMIES, and L. LAHTI. 1964. Cold-hardiness of the newly hatched young in relation to ecology and distribution in ten species of European ducks. *Auk* 81 : 281-307.
LACK, D. 1968a. The proportion of yolk in the eggs of waterfowl. *Wildfowl* 19 : 67-69.
LACK, D. 1968b. *Ecological Adaptations for Breeding in Birds.* London: Methuen.
LACK, D. 1970. The endemic ducks of remote islands. *Wildfowl* 21 : 5-10.
MARCSTROM, V. 1966. Mallard ducklings (*Anas platyrhynchos* L.) during the first days after hatching. *Viltrevy* 4 : 343-70.
MATTHEWS, G. V. T. and C. R. G. CAMPBELL. 1969. Weights and measurements of Greylag Geese in Scotland. *Wildfowl* 20 : 86-93.
MINISTY OF AGRICULTURE, FISHERIES AND FOOD. 1960. *Ducks and Geese.* Bulletin No. 70.
MCKINNEY, D. F. 1965. The comfort movements of Anatidae. *Behaviour* 25 : 120-220.
NIETHAMMER, G. 1938. *Handbuch der deutschen Vogelkunde.* Vol. 2. Leipzig.
PHILLIPS, J. C. 1926. *A Natural History of the Ducks.* Boston: Houghton Mifflin.
PORTMAN, A. 1950. Le Developpement postembryonnaire. In *Traite de Zoologie.* Vol. 15. Paris: Masson et Cie.
SCHIØLER, E. L. 1926. *Danmarks Fugle.* Vol. 2. Copenhagen.
SCHÖNWETTER, M. 1960-61. *Handbuch der Oologie.* Ed. W. Meise. Berlin: Akademie-Verlag.
SMART, G. 1965. Body weights of newly hatched Anatidae. *Auk* 82 : 645-8.
SOUTHWICK, C. 1953. A system of age classification for field studies of waterfowl broods. *J. Wildl. Mgmt.* 17 : 1-8.
STRESEMAN, E. 1931. *Handbuch der Zoologie. Aves.* Vol. 7. Berlin.
VESELOVSKY, Z. 1951. Postembryonalni vyvojkachny chocholate (*Nyroca fuligula* L.) *Sylvia* 12 : 1-19.
VESELOVSKY, Z. 1953. Postembryonalni vyvoj nasich divokych kachen. *Sylvia* 14 : 36-73.
VESELOVSKY, Z. 1966. Beitrag zur Kenntnis der systematischen stellung der Kolbenente (*Netta rufina* Pallas). *Vestn. Cs. Spol. zool.* 30 : 77-90.
WELLER, M. W. 1957. Growth, weights and plumages of the redhead, *Aythya americana. Wilson Bull.* 69 : 5-38.
WITHERBY, H. F. *et al.* 1939. *The Handbook of British Birds.* Vol. 3. London: Witherby.

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